Panel Review of:

A Stock Assessment of Eastern Oyster, *Crassotrea virginica*, in Maryland Waters of Chesapeake Bay

April 23-24, 2025
Annapolis, MD

Panel Members

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Introduction

This report presents results of external peer review of an assessment of oysters in Maryland's portion of Chesapeake Bay. The assessment was conducted by the Maryland DNR in consultation with the University of Maryland Center for Environmental Science (UMCES) and was completed on March 14, 2025. The review was conducted by a panel of external experts in April 2025 following Terms of Reference reviewed by the Maryland Oyster Advisory Commission.

Background

The Chesapeake Bay was a leading producer of oysters globally in the late 1800's; however, declines in water quality, the introduction of oyster diseases, and overfishing generated severe stock declines over the following century (Rothschild et al., 1994). Efforts to recover these depleted stocks and their habitats began in earnest in the 1990's with enhancement of habitats through shell addition and by transplanting cultivated and wild oyster seed (Kennedy et al., 2011). The decline in the resource has led to initiation of several long-term monitoring studies, a variety of intensive efforts to rehabilitate the resource (Kennedy et al. 2011), and many concerns about the health of the Chesapeake Bay ecosystem. In 2023, the Maryland Department of Natural Resources amended its 2019 Oyster Management Plan (OMP) to reflect several recommendations from the Oyster Advisory Commission related to oyster stocks, their habitat and ecology, fisheries, and requiring the use of scientific information to support rebuilding oyster populations.

The first stock assessment was completed in 2018 by a stock assessment team consisting of shellfish scientists, statisticians and stock assessment experts from Maryland DNR and the University of Maryland Center for Environmental Studies (UMCES), many of whom remain on the team who completed the assessment under review. The assessment being reviewed herein is the second stock assessment of Maryland oysters, and it is anticipated that full assessment and review will repeat every 6 years henceforth. A complete list of participants in the 2024 stock assessment reporting and review is provided in Appendix 3.

This report provides a record of the findings of the peer review conducted April 23-24, 2025 in Annapolis, MD. The Review Panel were provided written material in advance of the meeting which included the draft stock assessment report and were provided several presentations made by the Assessment Team at the meeting to review the report materials and findings. The Assessment Team (and managers) responded to questions during the meeting and provided additional analyses as requested. This report summarized the review process and provides the results of the review. The report has been reviewed by the Assessment Team for factual errors but opinions and conclusions of the Review Panel have not been altered.

Review Process

The review process comprised several emails prior to the review, a two-day hybrid meeting attended by the Assessment Team, which included staff from Maryland DNR and from UMCES, and the Review Panel. The hybrid meeting was followed up with a collective writing period by the Review Panel during which this report was completed. A complete list of the participants at the meeting and their roles may be found in Appendix 3.

The meeting was held in a ground floor meeting room in the Crowne Plaza Hotel Annapolis (173 Jennifer Road, Annapolis, MD 21401) on Wednesday, April 23, 2025 and Thursday, April 24, 2025. Support from the Assessment Team was excellent, providing expertise in oyster biology, survey operations, and fisheries. The Assessment Team was organized, well prepared, and shared insightful summaries of the data and models. They responded to detailed questions about the report and engaged in meaningful discussions about underlying processes and consequences of choices made in data-handling and model operations. The Assessment Team were receptive to requests from the Panel to conduct additional analyses. All presentations of and decisions about the data quality and model structure were open and transparent.

Special thanks are given to Kaitlynn Wade for her comprehensive service as rapporteur and Patrick Campfield for helping coordinate meeting travel and logistics.

Primary Conclusions

The Review Panel appreciated the concise and clear format of the assessment report provided. Additional materials were available as needed yet were not merged with the information directly relevant to the assessment which helped in reviewing pertinent material. The inclusion of model equations and assumptions further expedited review of the assessment report and its underlying approach. The introduction to the report included a great deal of ancillary summation of the ecology of the Chesapeake Bay that isn't used in the assessment. The Review Panel recommends restricting some of the introductory material in the report to those elements of direct importance to the assessment and its relevance. In addition, the introduction would benefit from additional information about the management process and assessment timing (e.g. model update every two years; benchmark every 6) to establish where this assessment sits relative to previous assessments and model changes (though we note that this information was provided during the review itself).

Overall, the Review Panel concluded that all Terms of Reference had been met. The Review Panel supported the conclusions of the Assessment Team and agreed that they had fully utilized the available data at an appropriate temporal and spatial resolution. The modeling approach is innovative and the results can serve as a reliable basis for management decisions.

Panel Review of Terms of Reference

The following is a summary of the Review Panel's appraisal of the Assessment Team's satisfactory completion of each Term of Reference (TOR). A full list of the original Terms of Reference, as provided to the Review Panel is provided in Appendix 2.

TOR 1a – Data Review

Panel conclusion → the assessment team met this TOR.

The Assessment Team provided a thorough review of relevant data in the report. This review included survey data, reported harvest and effort data, studies and data related to population rates (growth, mortality and recruitment), available substrate, shell budgets, and sources of mortality.

Fishery dependent data included buy ticket (or dealer level) data and individual harvester reports. An additional data source, the per-bushel tax on harvested bushels, was used as a proxy for harvest. The Assessment Team reviewed the historical record of these data and identified certain overlap and discrepancies among the data sources that were used to correct for underreporting. This correction factor adds 10% to the buy ticket harvest to account for assumed underreporting (this assumption was explored as a sensitivity analysis by the assessment team; e.g., Figure 201 of full report).

It was noted that buy ticket data may be more reliably reported, has daily resolution, and provides additional information about how many licenses may have been fished on a single vessel in a single day whereas harvester reports would not include this information. The combination of buy ticket and harvester report data are used to derive patterns of harvest effort annually over time, spatially by NOAA code, and by gear type.

Harvest effort in bushels was converted to number of individual oysters for use in the population dynamics model with a single oysters per bushel conversion factor. This conversion factor is an average oyster count derived from a relatively small number of samples collected during dockside monitoring in 2017. This sampling effort measured the number of oysters per bushel over 20 bushels in total, resulting in a coefficient of variation of 30%. The Review Panel noted that this data (oyster count per bushel) can vary in time and space, and given the importance as a conversion factor for harvest to individual oysters for modeling, more observations should help improve future assessments.

Fishery independent data include the fall dredge survey, bottom habitat surveys, restoration efforts, and patent tong surveys. Dredge surveys conducted by Maryland DNR have a long history, starting in 1939. Much of the historical raw data have been lost, and only index data remain prior to 1970. From 1975 onwards, 53 'key bars' have been sampled repeatedly to provide an index of spatfall at fixed locations. Oyster parasite prevalence and intensity (disease data) have been collected at 31 of the 53 'key bars' since 1990, and since 2005 tow distances for each tow in the fall dredge survey were recorded allowing CPUE per sample to be estimated. The Assessment Team limited the fall dredge survey data used in this assessment to those samples collected since 2005 because they provided standardized catch information. The Review Panel supports this decision.

On rare occasions, a station in the fall survey retrieved a full dredge. These samples are problematic because it is uncertain how much CPUE is underestimated by the full dredge being unable to continue sampling once full. At the same time, these stations disproportionately represent high abundance stations as those are locations where the dredge would fill completely. The assessment model is sensitive to inclusion of these stations as evident when the full tows were discarded from the fall survey dataset in sensitivity runs. Indeed, the Review Panel notes that for patchy species like oysters, these rare, high abundance observations are often important for overall population estimates. The Assessment and Survey Teams noted that these full dredge tow observations are becoming less frequent through time, and future surveys will resample these stations to eliminate full dredge tows from the survey.

Bottom habitat survey data from the Yates survey (conducted 1906-1912) and the Maryland Bottom Survey (conducted 1975-1983) are used to estimate oyster bottom habitat area. The oyster habitat area is used with the oyster density data from the fall survey to scale the oyster density from the survey to an entire NOAA code; therefore, the estimates of oyster abundance are highly sensitive to habitat area. An effort is underway to fully characterize bottom habitat throughout the Maryland portion of the Chesapeake Bay to provide updated and possibly higher resolution data for habitat. The Assessment Team is working with those involved and intend to use those updated data when they become available for use. Updated habitat information will help improve the scale of the estimates of oyster abundance.

Oyster replenishment and restoration is common in Maryland and has been conducted on nearly all bars over time. Enhancements include planting shell or non-shell substrates, transplanting wild oysters, or planting hatchery produced oysters. Reliable GIS records have been kept of all of these restoration efforts since 2005. The planted footprint of the area enhanced can be estimated from the data and are used to convert restoration to either habitat or individual oysters.

Patent tong survey data are available over various spatial and temporal scales and for various purposes. Catchability of the gear is uncertain and most of the patent tong survey effort is within restored sanctuary habitats which likely misrepresent oyster density on fished grounds. For these reasons, the Assessment Team chose not to use the patent tong survey data in this assessment. The Review Panel supports this decision, agreeing that the fall survey data is much more comprehensive, consistent, and appropriate for use in the assessment.

Currently, catchability of the dredge used in the fall survey is borrowed from that estimated for a survey dredge used in the N.J. Delaware Bay oyster stock assessment (Powell et al., 2007; Marenghi et al., 2017). Gear efficiency is known to vary across survey platforms and even through space and target species density (Morson et al., 2018). The Review Panel notes that a direct evaluation of the efficiency of the dredge used in the fall survey would improve the reliability of the data being used from that survey. Additionally, cross-validation of the dredge used in the fall survey with the patent tongs used for other surveys may allow the patent tong survey data to be added to the fishery independent data for this assessment.

TOR 1b – Spatial and Temporal Data Application

Panel conclusion → the assessment team met this TOR.

The assessment team elected to conduct the assessment at a NOAA code level of spatial resolution. The Panel was supportive of using NOAA codes (comments below notwithstanding) and of excluding sanctuaries, since they are not part of the fishery (their purpose is to support research, education, and/or restoration goals), and abundances within sanctuaries may not be representative of abundances outside sanctuaries. There are 47 NOAA codes used to report shellfish harvest; twelve were removed from consideration due to jurisdictional and data availability issues, ultimately resulting in 35 NOAA codes used in the assessment (Figure 3 from main report). To provide a sense of scale, the mean size of a NOAA code is approximately 32K acres, or about twice the size of Manhattan, NY.

The Panel discussed with the assessment team the possibility of estimating parameters (e.g., transition probability) by groups of NOAA codes. The assessment team thought variability within a NOAA code was high enough to justify a single code as the appropriate spatial scale, not wanting to smooth over too much variability by combining NOAA codes, and the Panel thought that was a reasonable position to take, though the Panel believes there is an opportunity to explore this further as part of future assessments (e.g., Mace et al. 2021).

Parameter priors were informed by studies covering a range of appropriate temporal and spatial scales that are adequately described in the report. The Panel noted that additional dredge efficiency experiments are available that were not included, and the assessment team noted the exclusion was intentional so as not to include efficiency studies reliant on patent tongs with estimated 30% efficiency (Wilberg et al. 2022).

In terms of temporal scale, the assessment team chose to start the assessment in the 2005/2006 season, the year in which the fall dredge survey started recording tow distance using a hand-held GPS unit, and the Panel was supportive of this decision as it allowed for quantitative swept area estimation of oyster and box densities with which the model was fit.

TOR 1c – Data Changes Over Time

Panel conclusion → the assessment team met this TOR.

The report does a very good job of describing data collection protocols and data quality over time. The assessment team highlighted a few specific examples during the review, but again, the report describes the data sources in good detail (e.g., changes in reporting rate of harvest records, Figure 10 from full report).

Starting the assessment in 2005/2006 appears to have bypassed most, though not all, changes in data collection protocols. For example, methods to quantify habitat have changed over time, but are clearly documented in the report (e.g., Section 2.2.2), and were discussed during the review.

Additionally, and as noted above, tow distances were measured starting in 2005, and so starting the assessment in this season (2005/2006) bypasses the change in protocol prior to this year/season.

The report notes that prior to 2010 there were issues within the data concerning both precision and completeness of replenishment and restoration records and care must therefore be used when trying to infer total planting volume within a given area; it was not entirely clear from the report or review how this was addressed. Uncertainty here would cascade to uncertainty in estimates of abundance and estimates of adjusted exploitation rates. That uncertainty would appear limited to the first ~5 seasons of the assessment. The Panel also noted concerns related to the potential for overestimating habitat.

TOR 1d – Data Inclusion or Exclusion

Panel conclusion → the assessment team met this TOR.

The report does a good job of describing reasons for including or eliminating data sources [e.g., not including NOAA codes with sparse data or located outside of the jurisdiction of MD; justification for not using depletion analyses; justification for not using patent tong data (small spatial scale sampling & uncertainty related to efficiency); etc.].

The Panel discussed with the assessment team their decision to include full dredge tows from the fall survey in the model base run. The sensitivity analyses suggest that abundance is underestimated in those situations, since by definition, the dredge is not capturing all oysters in the path of the tow (not otherwise accounting for dredge efficiency). The assessment team indicated they deliberated on this point prior to completing the assessment, and felt either choice was reasonable, and balanced their concerns with the need for including as much data as possible. The Review Panel highlights that this is a source of uncertainty in the assessment, but, as shown in Tables 9 & 10 of the full report, this decision did not impact or change stock status relative to the base run. Additionally, the assessment team reported that there is a change in sampling protocol now that when a dredge tow is observed to be full, that tow is repeated, which should minimize the number of full dredge tow instances in the future.

TOR 2 – Assessment Model Development and Uncertainties

Panel conclusion → the assessment team met this TOR.

The assessment team and the report clearly lay out the data used in the assessment model, and the report clearly lays out the model equations used so that the reader can understand what was done and the assumptions made. The review team was appreciative of those efforts.

The assessment team noted that they explored a dynamic shell budget as part of this assessment, but the performance was poor so they elected not to include it in the final assessment document.

The Panel noted the reassuring population dynamics exhibited by the model estimates: for example, large recruitment events were generally followed by an increase in small oysters in the next year, then an increase in market oysters 1 or 2 years afterwards that tended to persist for several years. Where large drops in abundance occurred, they were generally paired with a large increase in M or harvest or both; the series of plots by NOAA code greatly facilitated these comparisons and observations. It was reassuring that the reader can follow cohorts through the population, and there are logical explanations for swings in abundance. There are instances where there are declines in small and market oyster abundance, without a concomitant increase in boxes, as we would expect if natural mortality caused the decline; the assessment team believes those instances may be cases of mis-reported or unreported landings.

The assessment team's sensitivity analyses were well done and informative; expected results were observed in response to the changes they implemented which was reassuring. For example, when the assessment team assumed that the mean q on adults was 2x higher than base run, it would suggest there are fewer market oysters relative to the base run, resulting in higher exploitation relative to the base run, and those were the observed results from the analysis; and the opposite was true when assuming adult q is 0.5x actual prior. The Panel did note however that in some cases while the mean response of a change in parameter = 0, there was a distribution of differences that in some cases could differ substantially from zero. The assessment team explained that in cases where there was a broader distribution of differences, they believed this resulted from NOAA grids that are lightly fished or lightly sampled (and hence, leading to a distribution of results, most often centered on zero).

The Panel spent a goodly amount of time talking about reference points with the assessment team. On this topic, most discussion focused on exploitation reference points.

The exploitation reference point was based on a rate of exploitation that would result in no net loss of oyster shell habitat over time. The reference point relies on a regression of year over year change in cultch (live oysters + shell in its various forms) from the fall dredge survey against exploitation rate estimated from the assessment model. In the Panel's view, this formulation implies a significant relationship between exploitation and habitat change; but the slope of the relationship was not significant ($p > 0.05$). After discussion with the Panel, the assessment team explored several additional analyses overnight that were presented the following day. Analyses explored included:

- GAM; results suggested a linear relationship (as in the original reference point formulation) was appropriate; the slope was not significant ($p>0.05$) but was negative.
- Logistic regression where habitat change was converted to 0/1 depending on whether habitat was lost or gained; the relationship was not significant, but again the slope was negative.
- Subsetting the data to just the 10 highest harvest NOAA codes to minimize potential noise coming from lightly exploited (and sampled) NOAA codes. The relationship was not significant, but the slope was again negative.
- Multiple regression with M as a covariate; M not significant, interaction not significant.
- Quantile regression – not able to explore overnight, but useful future exploration opportunity.

Given the consistent negative relationship between exploitation and habitat change (i.e., sensitives explored by assessment team prior to review & documented in the final report, as well as those explored during the review), and that the resulting reference point is broadly consistent with, though somewhat higher than, those seen in the Delaware Bay oyster fishery, the Panel thought the exploitation reference point was suitable for management. In light of the relatively weak and potentially volatile relationship between exploitation and habitat change (e.g., sensitivities explored by assessment team prior to review), the Panel suggests not updating reference points until the next benchmark assessment (~6 years; i.e., maintaining the current set of reference points in the interim).

The Panel and assessment team spent less time discussing abundance reference points. The Panel supported the lower limit and cautionary levels for management; these reference points were rooted in restoration goals developed for the Chesapeake Bay as part of a process that involved stakeholders which the panel viewed as a strength of the reference points. The target level abundance is based on 50% of the average oyster density from 2 sanctuary regions in the central part of the bay. The Panel expressed some initial concern but views the reference point as suitable for management given that the central part of the bay can represent an average abundance condition of sorts. Given that this reference point represents an average condition, the panel did wonder whether it was achievable in all regions of the bay. Future assessments might consider regional abundance reference points that might reflect regional biological constraints.

The Panel was supportive of the assessment team's decision to average the most recent 3 years abundance and exploitation when comparing assessment results to the respective reference points, though did suggest further exploration of interannual variability (e.g., 1 vs 2 vs … 5 year averages; CVs) as part of future assessments and consideration of providing additional information with the status determination (e.g., some indication of 3-year trend). The Panel also suggested future assessments might consider providing adjusted as well as unadjusted exploitation rates in the exploitation reference point table for comparison.

TOR 3 – Stock Status from Models

Panel conclusion → the assessment team met this TOR.

Both the 2018 assessment model and the 2025 assessment model were stage-based and both models used the same stages. The primary differences between the two models were the starting time point, calculations of abundance, and assumptions regarding habitat and habitat change over time. The 2018 model used data beginning in 1999, whereas the 2025 model used data beginning in 2005 coinciding with estimation of dredge tow length as part of the Fall Dredge Survey. As a result, indices of abundance in the 2018 model used oyster counts per bushel of cultch and the 2025 model used counts per unit area swept by dredge (i.e., oyster density). In the 2018 model, habitat was assumed to decline exponentially over time with augmentation from substrate planting. In contrast, the 2025 model assumed habitat area was constant over time.

In terms of model construction, the Review Panel agreed with the continued use of a stage-based model. The Review Panel supported truncation of the time series to begin in 2005 when oyster density from Fall Dredge Surveys became estimable. The Panel agreed with the assessment team's decision to remove the assumption of exponential habitat decline in the updated model, which panelists suggested likely improved model performance, is more consistent with Fall Dredge Survey observations of habitat and makes the model more biologically reasonable.

Estimates of abundance were generally higher in the 2025 model than in the 2018 model due, largely, to differences in modeled habitat change. Consequently, estimates of exploitation were generally lower in the 2025 model. Still, at almost all NOAA codes, status relative to abundance and exploitation reference points was the same, although the 2018 model reported status based on the terminal year and the 2025 model used a 3-year average. The Panel was onboard with the 3-year averaging approach, but did express some concern as to how sensitive status determinations were based on the length of the moving average. The Panel recommended updating the abundance reference point table comparing model outputs (Table 12) such that abundance was displayed for each NOAA code and model, which would make comparison among model outputs easier. The Panel also recommended adding adjusted and unadjusted exploitation rates for the exploitation rate model comparison Table (Table 13).

TOR 4 – Research Recommendations

Panel conclusion → the assessment team met this TOR.

The Review Panel identified several research recommendations that should be prioritized to support and improve the next benchmark assessment. Several research recommendations were also reflected in the stock assessment team's research recommendations included in the 2018 and 2025 oyster benchmark assessments (recommendations identified in the assessments are indicated as such in the list below).

Research Recommendations (in no specific order):

- Demographic rates and transition probabilities:
    - Compare transition probabilities used in the assessment with estimates from other systems (e.g., Theuerkauf et al. 2021; Johnson et al. 2023).
    - Explore how transition probabilities, and spatial variability therein, relate to known oyster ecology in NOAA codes.
    - Explore the use of environmental parameters (e.g., temperature and salinity) to develop NOAA code-specific priors.
    - *Need identified in 2018 and 2025 assessments*: Conduct research to better quantify growth rates that can be incorporated into stock assessment models.

- Expanded dockside monitoring:
    - Continue and expand (in space and time) dockside monitoring to improve conversions from catch reported in bushels to stage-specific oyster abundance.

    - *Need identified in 2018 and 2025 assessments*: Conduct fishery dependent sampling of oyster size distribution to better quantify the number of oysters per bushel and the number of under-sized oysters per bushel.

- Model spatial structure:
    - Explore grouping/stratifying NOAA codes such that groups of codes could have unique priors or reference points. The Review Panel acknowledged the clustering strategy applied in Mace et al., 2021 could be explored and/or further developed.
    - *Need identified in 2018 assessment*: Examine alternative spatial structure for stock assessment. *Progress since the 2018 assessment*: An alternative spatial structure was considered for the stock assessment, but the NOAA code spatial structure was considered to best match the understanding of the population dynamics and the information desired for fishery management.

- Fishing mortality:
    - Explore new ways of generating fishing mortality reference points that can vary spatially to incorporate ecological differences among regions and NOAA codes.
    - The Panel's understanding is that all oyster plantings within a NOAA code, regardless of location (e.g., even within sanctuary unavailable to the fishery), can offset exploitation (adjusted exploitation); exploring ways of fine-tuning the accounting of plantings can help refine the estimate of exploitation.
    - *Need identified in 2025 assessment:* Examine potential for survey samples taken after fishing season to inform estimates of fishing mortality in the assessment model.

- Stock status:
    - Explore additional ways of characterizing uncertainty and/or trend in the three-year terminal average metric used for creating summary outputs from the assessment.
    - Explore sensitivity of stock status to different time lengths of moving average (1 yr vs 3 yrs vs 5 yrs).

- Integrate environmental data:
    - Develop a climate-enhanced stock assessment model whereby environmental variables are integrated with the population dynamics model (for example, to esimation of M (see below), or further understanding the population and system dynamics). As an example, this could be explored using hindcast data from the Chesapeake Bay Observational Forecast System (CBOFS) to integrate temperature and salinity into the assessment model.

- Natural mortality:
    - Explore approaches for connecting disease data to natural mortality in the assessment model (e.g., see bullet above).
    - Explore using CBOFS to hindcast disease dynamics across NOAA codes.

    - Examine potential for survey samples taken from sanctuaries before and after fishing season to test winter natural mortality assumption.

- Habitat quantity and quality:
    - Examine how (or if) habitat quantity and quality change over time.
    - Develop and utilize remote sensing approaches that more rapidly measure habitat quantity while assessing habitat quality.
    - Develop a sampling protocol and model that not only includes habitat quantity but also habitat quality.
    - *Need identified in 2018 and 2025 assessments:* Examine updated habitat estimates as they become available from the recent Bay Bottom Survey for inclusion in the assessment model. Measure shell volume (separate from volume of live oysters) in Fall Dredge survey samples to potentially help with modeling changes in habitat volume over time. Develop a mechanism to better understand how shell plantings contribute to habitat and how habitat is quantified.

- Abundance targets:
    - Develop abundance targets based on biomass given the potential for density targets to potentially mislead without inclusion of size structure. This work will require developing NOAA code-specific (or appropriate groupings) length-biomass relationships.
    - Develop a model that separates sanctuary abundance from fished abundance so adjusted and unadjusted abundances can be calculated for reference point tables.
    - *Need identified in 2018 assessment*: Research on target levels of abundance including biological limits of abundance (e.g., necessary conditions for successful fertilization). *Progress since the 2018 assessment*: Developed target and limit levels of oyster abundance based on the abundance observed in the large-scale restoration areas and the targets used for evaluating success of the large-scale restoration areas.

- Shell budget
    - Develop a list of necessary research steps needed to model shell budgets. Address research topics identified.
    - Develop a dynamic shell budget/habitat model.
    - *Need identified in 2018 and 2025 assessments:* Incorporate a shell budget into stage structured assessment to allow internal estimation of biological reference points. Studies designed to quantify the rate of habitat decay would better inform the assessment and reference point models; and would contribute to development of a shell budget.

There were two additional research recommendations identified in the 2025 assessment that the Panel did not prioritize, but did provide some suggested research topics within each recommendation.

- *Need identified in 2025 assessment:* Revisit spatial aspects of the Fall Dredge Survey to determine the area that is represented by samples, especially with respect to the new

habitat data from the Bay Bottom Survey that is currently being conducted. Consider including a subset of random sites in the Fall Dredge Survey.
  - Review Panel suggestion: Conduct a sensitivity analysis removing FDS station(s) to see how sensitive model outputs are to fixed sample stations.

- *Need identified in 2025 assessment*: Conduct experiments to estimate catchability of the Fall Dredge Survey.
  - Review Panel suggestion: Conduct cross-calibration of the dredge used in the fall survey with the patent tongs used for other surveys to allow the patent tong survey data to be added to the fishery independent data for future assessments. Of note, calibrations are being considered in Delaware Bay in 2025.
  - Review Panel suggestion: Conduct cross-calibration of dredge used in fall dredge survey with oyster survey tools used elsewhere. As noted above, calibrations are being considered in Delaware Bay in fall 2025.

References

Johnson, F.A., Camp, E.V., Gandy, R., and Pine, W.E., 2023. Demography of Oysters Pre- and Post-collapse in Apalachicola Bay, Florida, Using Stage-Based Counts. Marine and Coastal Fisheries, 15(3): e10244, doi: 10.1002/mcf2.10244.

Kennedy, V.S., Breitburg, D.L., Christman, M.C., Luckenbach, M.W., Paynter, K., Kramer, J., Sellner, K.G., Dew-Baxter, J., Keller, C. and Mann, R., 2011. Lessons learned from efforts to restore oyster populations in Maryland and Virginia, 1990 to 2007. Journal of Shellfish Research, 30(3): 719-731.

Mace III, M. M., Doering, K. L., Wilberg, M. J., Larimer, A., Marenghi, F., Sharov, A., and Tarnowski, M., 2021. Spatial population dynamics of eastern oyster in the Chesapeake Bay, Maryland. Fisheries Research, 237: 105854.

Marenghi, F., Ashton-Alcox, K., Wong, R., Reynolds, B., and Ozbay, G., 2017. Dredge efficiency on natural oyster grounds in Delaware Bay and its application in monitoring the eastern oyster (*Crassostrea virginica*) stock in Delaware, USA. Fisheries Research, 186: 292–300.

Morson, J.M., Munroe, D.M., Ashton-Alcox, K.A., Powell, E.N., Bushek, D., and Gius, J., 2018. Density-dependent capture efficiency of a survey dredge and its influence on the stock assessment of eastern oysters (*Crassostrea virginica*) in Delaware Bay. Fisheries Research, 205: 115-121.

Powell, E. N., Ashton-Alcox, K. A., and Kraeuter, J.N., 2007. Reevaluation of eastern oyster dredge efficiency in survey mode: Application in stock assessment. North American Journal of Fisheries Management, 27(2): 492–511.

Rothschild, B.J., Ault, J.S., Goulletquer, P., and Heral, M., 1994. Decline of the Chesapeake Bay oyster population: a century of habitat destruction and overfishing. Marine Ecology Progress Series, 111: 29-39.

Theuerkauf, S.J., Puckett, B.J. and Eggleston, D.B., 2021. Metapopulation dynamics of oysters: sources, sinks, and implications for conservation and restoration. Ecosphere, 12(7): e03573, doi: 10.1002/ecs2.3573.

Wilberg, M.J., Coleman, S., Slacum, H.W., and Liang, D., 2022. Efficiency of Hydraulic Patent Tongs for Surveying Restored Eastern Oyster Reefs in Harris Creek, Maryland. North American Journal of Fisheries Management 42(4): 1011-1019.

Appendix 1 – Agenda

Draft Agenda
Oyster Stock Assessment Peer Review
Maryland April 23 - April 24, 2025
Crowne Plaza Annapolis
173 Jennifer Road
Annapolis, MD 21401

Panelists: Dr. Daphne Munroe (chair), Rutgers University; Dr. Brandon Puckett NOAA Beaufort Laboratory; Mike Celestino New Jersey Department of Environmental Protection

Day 1 – Wednesday April 23

8:00 - Welcome and introductions

8:15 - Presentation focusing on Term of References (TORs) - data. Includes context of assessment time frame, treatment and processing of data for input to assessment, development of priors for model

9:15 - Questions / discussion

10:00 - Presentation focusing on TORs – model description, diagnostics, results, biological reference points, and sensitivity analyses

11:30-1:00 – lunch

1:00 - Presentation focusing on TORs continued– model description, diagnostics, results, biological reference points, and sensitivity analyses

2:00 - Questions / discussion

5:00 - Adjourn

Day 2 – Thursday April 24

8:00 - Resolution of any issues from the previous day

9:00 - Presentation focused on TORs – Comparison with of results with previous model and justify selection.

9:30 - Questions from peer review panel

11:30-1:00 – lunch

1:00 - Closed session for peer review panel to begin drafting report.

stock assessment team - on call.

4:00 - Reconvene with assessment team to go over initial conclusions.

5:00 - Adjourn

Appendix 2 – Terms of Reference

Maryland Oyster Stock Assessment

Terms of Reference

1) Complete a thorough data review: survey data, reported harvest and effort data, studies and data related to population rates (growth, mortality and recruitment), available substrate, shell budgets, and sources of mortality.

> a) List, review, and evaluate the strengths and weaknesses of all available data sources for completeness and utility for stock assessment analysis, including current and historical fishery-dependent and fishery-independent data.
>
> b) Identify the relevant spatial and temporal application of data sources.
>
> c) Document changes in data collection protocols and data quality over time.
>
> d) Justify inclusion or elimination of each data source.

2) Develop a stock assessment model (or models) that estimates status of the stock relative to biological reference points. To the extent possible, quantify sources of uncertainty within model.

3) Compare estimates of stock status generated by the previous assessment model with the new model. Justify selected approach.

4) Provide research recommendations for improving the stock assessment.

Appendix 3 – List of Participants

Name	*Affiliation*	*Email*
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